November 2011

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Contents

1 Introduction

This report summarises work undertaken by Arup, on behalf of the MBE KTN, for the National Platform for the Built Environment to identify challenges faced by the UK construction industry.

Identification of these challenges is the first step to inform strategic research priorities that the National Platform will promote within the construction industry and research funding bodies such as research councils, Technology Strategy Board and European funding programmes.

2 Context

This section sets out the context for research activity within UK construction industry. It briefly describes construction industry characteristics, in particular those that hinder successful delivery of research within the industry, relationships between the parties funding and delivering research, types of problems in the industry that have a research element to their solution, and finally, the implication of this context for the UK construction industry priorities.

The construction industry in the UK employs around 1.5 million people and, accounts for about 5-10% of GDP. Approximately 50% of building work is generated from private clients, and 50% from central and local government, so construction output inevitably fluctuates in accordance with economic and political cycles. to the UK's offshore location from mainland Europe has historically resulted in a relative absence of overseas competition and a culture that does not perceive the imperative for change.

The construction industry covers a wide range of activities brought together by a common interest in development of land and real estate. The sector comprises a variety of interests that include designers, suppliers, contractors and clients (who can be industrial firms, commercial property developers and government departments, each of which may have a varying degree of experience in procuring construction projects). The separation of activities of these parties results in the fragmented nature of the industry. In addition, the supply chain itself is also fragmented, composed of a large number of small firms. This makes the industry inert to any step changes.

The complex nature of procurement and uncertainty at the project outset regarding time, cost and quality of the final product, low level of standardisation, inefficient and wasteful procurement, and adversarial working relationships all result in the industry having a poor image. This has triggered a longstanding agenda for modernisation and performance improvement. The curent economic climate reinforces this agenda and requires a departure from the traditional model prevalent during more prosperous times where competitive advantage in construction was developed through cost efficiency rather than through investment in innovation.

The UK has ambition to remain a world leader in science, research and innovation. As such, research should become embedded into procurement of major engineering projects. However, currently the construction industry has low profitability, a culture of risk-aversion and a reluctance to innovate. It invests too little in capital, R&D and training, and its record of formally recorded R&D as a proportion of output is poor by the standards of other industries. Contributory factors include:

- High level of uncertainty at conceptual stage involved in innovative projects: managing out this uncertainty requires additional investment of time (and cost); availability of clear government priorities and plans would enable industry to plan and invest in innovation.
- Long project life cycle: it can take years before the team can learn from the performance of their product. It is essential to find new ways of developing standards and guidance rapidly, to meet the need for more rapid feedback from novel prototype to industry adoption.
- Logistical challenges of construction make it harder to adopt new technologies: it is essential to investigate why some innovations are slow to be taken up compared with other countries (e.g. CHP, light rail) to better understand the barriers to adoption.

Procurement of research in the construction industry is also fragmented, as are the sources of funding for this activity (see **Figure 1** below). Current distribution of research funding reinforces narrow focus on building process and cost rather than on constructed outcome (value of built environment to economy and society). Such narrowly focused R&D is unlikely to result in major benefit to project-based industries such as construction.

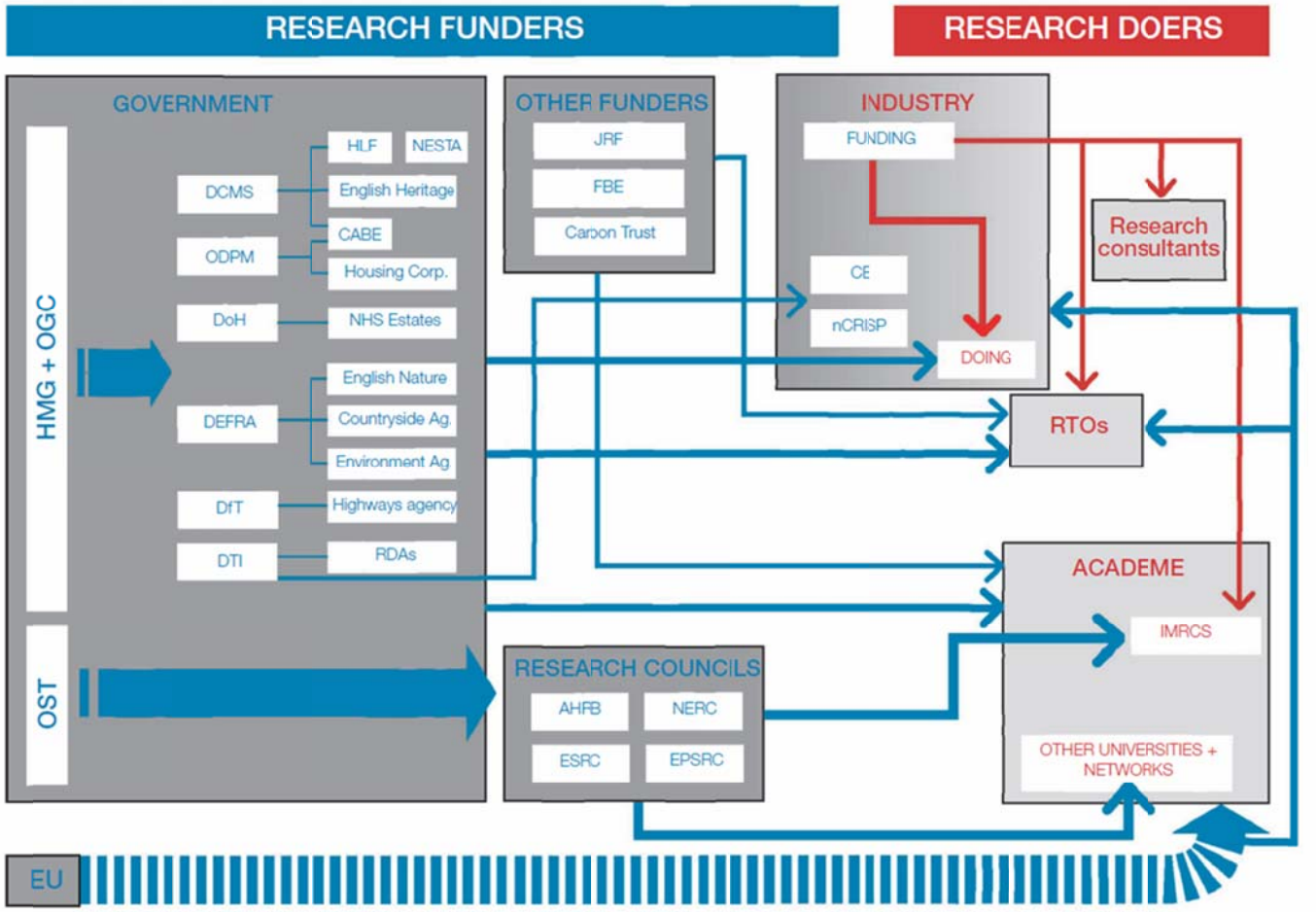


Figure 1 (source: "The real budget for research: an analysis of current levels of public funding for built environment research" CABE)

Built environment research coverage is currently imbalanced, with focus on 'hard' topics (durability, technologies, materials) rather than 'soft' topics (value of spaces, interaction of people with buildings, how buildings are used), and requires transition from traditional areas of conventional materials research to newer fields looking at process, management, productivity, value for money, behavioural aspects. The construction industry needs a better understanding of the extent and nature of its R&D activity, and to take an active role in setting its R&D priorities, based on strategic analysis of the issues faced by the sector.

R&D procurement needs to be tailored to reflect the various motivations for government support (regulator, sponsor, client, policy maker) and research needs to be procured on merit, encouraging centres and networks of excellence, delivered by multi-disciplinary teams with more interchange of people between industry and academe. This will enable exploration of which scientific breakthroughs and new technologies in automotive, aerospace, material science or IT may result in breakthrough application in the construction sector.

Demand for construction research involves solving scientific, technical, social, economic and environmental problems of three kinds:

- Problems where there is some degree of predictability about future trends and requirements
- Problems where there is little predictability, but where government and industry needs capabilities to respond quickly to unforeseen problems or events
- Development of new ideas and knowledge

3 Desk study

The challenges for the construction industry have been identified through a desk study of recent construction sector review reports and existing construction sector research roadmaps. The full list of references is provided in **Appendix A**.

Key recent documents were reviewed in detail; others through an overview of executive summary and key recommendations. In addition, we compared the identified challenges with main themes from existing research roadmaps.

Some of the reviewed documents explicitly stated research topics or areas, which we highlighted where applicable, but the focus of the review has been specifically on identifying challenges.

4 About the reviewed documents

Industry review reports

Construction industry review reports have different characteristics, sometimes overlapping, sometimes distinct functions, that can be classified as follows:

- Analysis of current situation in the industry, internal trends and need for change
- Setting a vision / goals / objectives for the future of the industry
- Analysis of constraints / barriers preventing change
- Focus on opportunities, enablers and mechanisms for change
- Analysis of external trends and drivers setting the wider context in which the industry operates
- Implications of external trends and required response from the industry (or from other parties)

Research roadmaps

The **roadmaps** had the following functions:

- Set out high level strategic priorities and needs
- Identify gaps in knowledge

5 Definition and analysis of challenges

5.1 What is a ‘challenge’?

In this project we attempted to frame issues identified in the literature review in terms of challenges.

A dictionary definition of a “challenge” describes it as a “*task or situation that tests someone’s abilities or resources*”, “*demanding or difficult but stimulating undertaking*”, “*a call to engage in a competition*”, or “*something that by its nature or character serves as a call to special effort*”.

5.2 Types of issues

The issues identified in the literature review can be classified as:

- trends
- implications
- responses
- needs
- constraints
- enablers
- visions

- research topics (more often than not, these are not explicitly stated)

Some of the reviewed documents explain interdependencies between different issues, some focus only on a selected issue. Functions of some issues are overlapping, for example:

- an ‘implication’ may have the form of a ‘need’;
- the ‘need’ may be for a new ‘enabler’;
- the required ‘response’ may be to carry out ‘research’;
- a ‘constraint’ may be lack of understanding of a certain issue, hence pointing to ‘research’.

In addition the same issue can be re-phrased in different terms, for example:

- Vision: efficiency in construction
- Response: improve efficiency of construction
- Research: how to improve efficiency of construction?

5.3 Framing issues as ‘challenges’

In the light of the above, we chose to frame a ‘challenge’ as:

“*practical need specific to the construction industry that arises as an implication of general trends and visions, whose realisation may be hindered due to constraints, and which requires specific responses or enablers*”

The logic is depicted in **Figure 2** below:

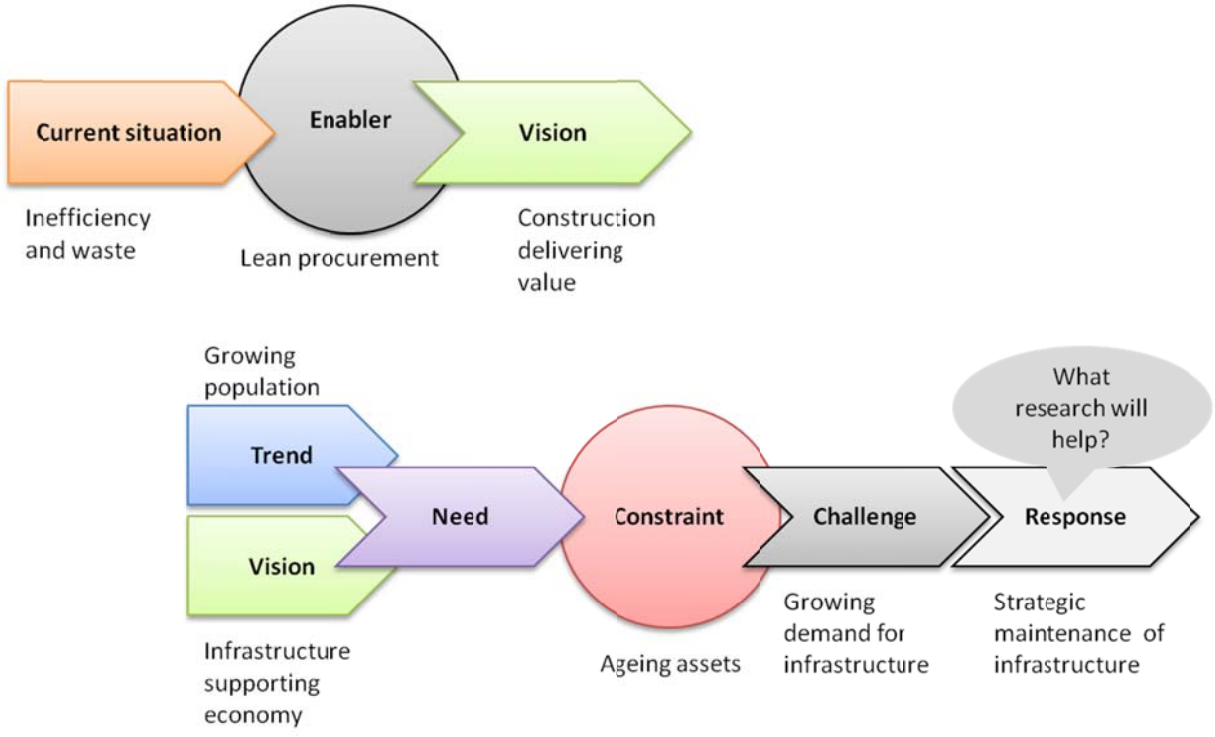
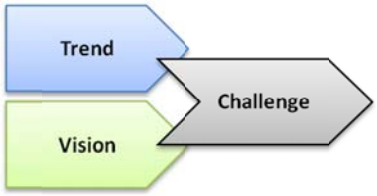


Figure 2 Framing issues as challenges

6 Method

6.1 Outline approach

Challenges were identified in line with the above definition through a combination of top-down and bottom up approaches explained in **Section 5.2**.



Challenges were then analysed and listed together with the example Responses and Research topics (only listed if explicitly stated in the reviewed documents), cross-referenced to the literature sources. (A full list of cross references is available in a spreadsheet format.)

6.1.1 Step 1: identification of challenges

Identification of challenges has been through a combination of top-down and bottom-up approaches.

In the top-down approach (**Figure 3**), challenges arise from a combination of various trends, visions and constraints and gives justification for why particular challenges are important.

In the bottom-up approach (**Figure 4**), challenges are listed loosely as they arise from literature review, and then categorised into groups identified through top-down approach.

The overall mapping of challenges is presented in **Figure 5**.

Construction industry characteristics are used as background information, and where relevant, help formulate challenges related to achieving a vision.

6.1.2 Step 2: analysis of challenges

Analysis of challenges is included in the remainder of this report (**Section 7** onwards). Note that in the analysis of challenges, impact and urgency has not been assessed – this is part of the requirements for 'next steps'.

6.1.3 Next steps

As a next step, the Challenges and Responses should be subject to a wider consultation with the industry in order to prioritise them according to their level of impact and urgency. The consultation should also suggest additional Responses to those identified in the literature review, and corresponding detailed Research topics.

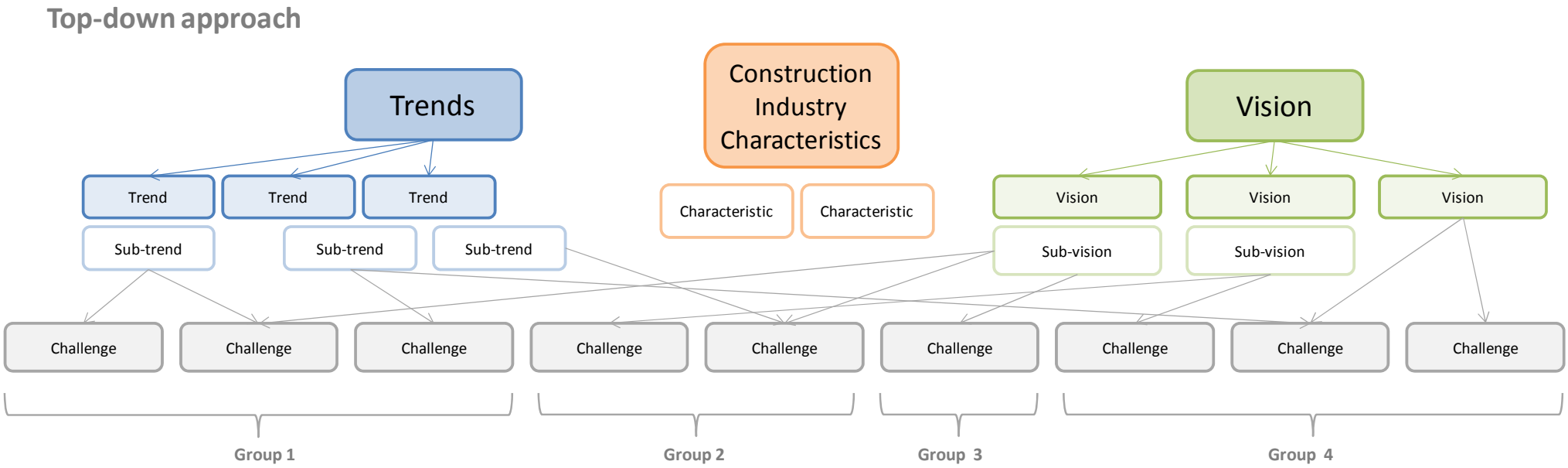


Figure 3 Top down approach

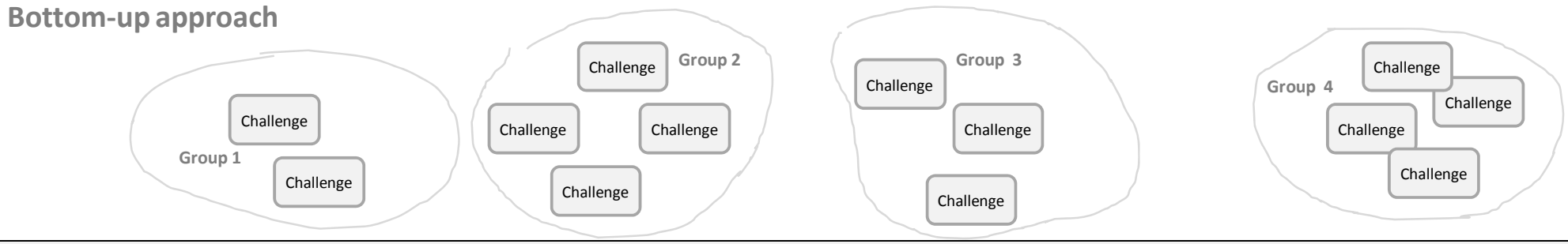


Figure 4 Bottom up approach

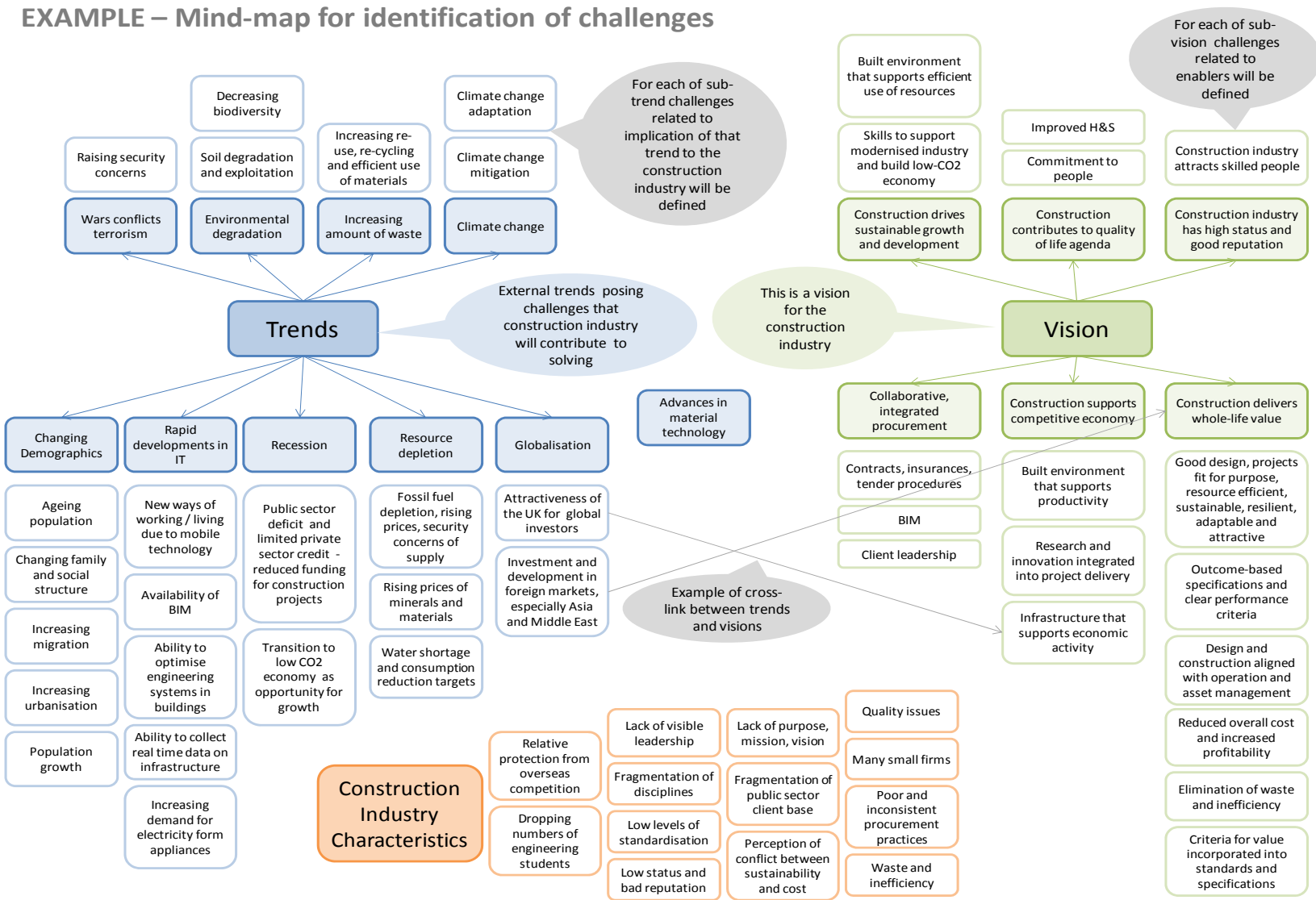


Figure 5 Mapping of challenges

7 Summary of main themes

We have grouped and analysed the Challenges according to themes, each of which is examined in a separate section of the report. The themes correspond somewhat to sub-trends and sub-visions (ref Figure 5).

Theme		Sub-themes
(1) Demographics		Ageing population Changing family and social structures Migration Urbanisation and expansion of cities Population growth
(2) Global Economy		Globalisation Recession Resource depletion
(3) Climate change adaptation		Higher average temperatures and heat waves Rising sea levels Flooding Heavy prolonged rainfall Droughts High winds Stability and moisture of soil
(4) Resilience, safety, security and hazards		Uncertainty of future requirements and conditions Increasing reliance on infrastructure Interdependencies of infrastructure networks Ageing infrastructure in developing countries Security and safety concerns Complexity and variety of hazards
(5) Climate change mitigation	**Energy generation and supply**	Energy security Decarbonisation of the power sector Efficiency of energy distribution, use and recovery
	Carbon in project design	Carbon in project appraisal Carbon in construction supply chain Carbon reduction versus wider performance
	Low carbon economy	Low carbon infrastructure Low carbon buildings
(6) Wellbeing and value		Cost versus value Construction providing wellbeing and quality of life
(7) Industry	**Capability**	Skills, reputation, leadership
	Procurement	Modernisation, integration, collaboration, client
	Performance	Quality, predictability, cost, productivity, efficiency

8 Theme 1: Demographics

	Main Challenges	Impact	Urgency	Example Responses
Demographics				
Ageing population	Increased demand for healthcare and different forms of healthcare			• Provide more hospitals and adapt design of houses to enable in-home care
	Facilitate the needs of the elderly			• Adapt built environment to meet the needs of an ageing population
Changing family and social structures	Increasing demand for housing due to growing number of smaller households			• Provide more housing at price which is affordable for buyers, commercially viable and contributes to zero carbon targets, with maximum use of brownfield sites. • Identify the business and regulatory risks inhibiting free development of long-term private investment; Identify marketing and other factors constraining optimum build-out rates on large sites
	Demand for infrastructure adequate to changing patterns of economic and social activity			• Need to adapt infrastructure to facilitate new ways of working / living: remote working, flexible working and work-life balance, work-related and leisure mobility, and movement of goods and ideas • Develop communication networks that transmit information to all parts of the UK at high speed;
Migration	Increasing migrant workforce			• Adapt H&S practices to cater for migrant workers
Urbanisation and expansion of cities	Create urban places ensuring social cohesion			• Improve construction performance with respect to people issues, safety, heath in the built environment and impacts on the wider community • Place requirement on house builders to play an active role in community management • Reduce environmental and man-made impacts of built environment and cities;
	Create buildings ensuring occupant wellbeing			• Improve construction performance in respect for people issues, safety, heath in buildings • Integrate thinking on human factors in the construction process and promote human-centred design • Align design and construction with operation and asset management
	Increasing reliance on infrastructure networks and growing demand for reliable and just-in time services			• Provide resilient infrastructure enabling movement of goods and ideas in reliable ways • Methods for identification of critical infrastructure • Methods for analysis of systems inter-dependence
Population growth	Increased demand for infrastructure causing increasing intensity of usage of existing networks and congestion			• Maximise the potential of existing infrastructure assets, in particular road and rail networks, through better management of existing assets and demand management; • Transform the capacity and connectivity of key urban and inter-urban rail networks. • Improve quality of data held in relation to economic infrastructure to assist development of a better understanding of key drivers of infrastructure demand, usage and cost
	Increased demand for and use of resources (energy, water) and growing importance of biofuels versus food production dilemma			• Maximise efficiency of resource use through demand management and provision of energy and water saving systems; develop innovative technologies including those that manage demand • Establish a more integrated understanding of water systems in order to optimise water supply, treatment and distribution process; • Develop methods for long term water management planning that fully consider the uncertainties related to climate and socio-economic change (real options, adaptive management)

9 Theme 2: Global Economy

	Main Challenges	Impact	Urgency	Example Responses
Global Economy				
Globalisation	Support global competitiveness of UK economy and attract to the UK investment related to R&D intensive projects			• Maintain and provide high quality infrastructure that supports economic activity and matches up to heavy investment in infrastructure in developing countries (remove transport bottlenecks; make better use of existing assets e.g. motorway management schemes; managing airport capacity and improving passenger experience; development of ports to handle increasing traffic) • Provide best superfast broadband in Europe to support business productivity and growth through more efficient ways of working, exchange of information with suppliers and customers • Use infrastructure investment programme to rebalance economy across all regions, e.g. through development of strategic rail network; improve journey times on key inter-urban routes, high speed rail
	Compete for work in BRIC countries during period of slowdown in construction market in Europe			• Understand construction markets and construction practices in developing countries • Offer services and skills applicable to problems in overseas markets
	Compete with overseas construction and manufacturing firms on the UK market			• Understand implications of construction productivity for international competitiveness • Reduce cost and improve quality of construction • Embrace new technologies (materials, IT, off site manufacture) as key to UK competitiveness • Improve innovation within supply chain • Consolidation of firms into multicultural enterprises;
	Growing investment from foreign clients			• Reconcile internationalisation of production ownership and use of buildings with meeting local needs and satisfying end users
Recession	Decrease in construction investment and output: in public sector due to budget deficit and government spending cuts in private sector due to limited credit shrinking working-age population constraining economic growth			• Identify and use new ways of funding construction projects • Build more for less - reduce cost of construction and provide better value for money • Save costs through product and process innovation, and economies of scale; • Identify opportunities for cost reduction through standardisation • Improve cooperation between public and private sectors • Attract greater private investment to fill public deficit gaps • Smarter use of public funding, improving private sector investment models, encourage new sources of private capital and address the regulatory failures that stand in the way of greater private sector investment • New hierarchy of infrastructure investment: maintenance and smarter use of assets; targeted action to tackle network stress points and network development; delivering transformational large-scale project that are part of clear long-term strategy • Ensure that infrastructure investment, in particular in maintenance of ageing assets, achieves affordable mix of public and private sector funding
	Availability of funding for transition to low-CO2 economy, cost of low-CO2 buildings and low-CO2 technologies			• Government to implement a package of incentives • Investigate the scope for funding transition to low-CO2 economy from savings in energy bills • Provide small-scale renewable systems that are cheap relative to the return they provide • Produce on/in house renewable energy generation solutions at similar cost to existing heating technology. • Use development of low-CO2 economy as an opportunity for growth • Sell low-CO2 construction and sustainability skills overseas • Large-scale production enabled by clear government strategy and market demand for marginal solutions to become viable. Government to implement package of incentives such as Green Deal
	Long period of recovery from recession and uncertainty of future workload due to project delays and cancellations			• Government to reduce volatility and uncertainty in workflow and funding, publish forward programme of works • Improve clarity of the complex institutional landscape, responsibilities and spending
	Tendency to abandon partnering in favour of lowest price tenders			• Initiatives to combat adversarial culture (e.g. participation in low margin jobs and earning profits through claims) and encourage partnering
Resource depletion and environmental degradation	Rising prices of minerals and construction materials			• Eliminate construction waste • Use materials efficiently to reduce amount of waste produced • Maximise re-use and recycling; improve understanding of design for re-use and recycling • Recover energy from residual waste especially rare elements and metals; landfill used as a last resort • Develop capability for a cultural shift to consider everything as commodity rather than waste
	Insecurity of fossil fuel supply and energy generation; volatile energy costs			• Change in energy generation and energy infrastructure • Provide infrastructure for renewable and nuclear energy generation
	Environmental cost of construction			• Sustainability agenda • Protection of biodiversity
	Provide built environment that supports efficient use of resources			• Energy efficient buildings; infrastructure systems influencing better consumer behaviour patterns

10 Theme 3: Climate change adaptation

		Main Challenges	Impact	Urgency	Example Responses
Climate change adaptation					
Higher average temperatures and heat waves		Risk of overheating in buildings from increased temperatures			• Understand the potential impact and likelihood of overheating in buildings; • Design new and retrofit existing buildings to protect occupants from high levels of thermal discomfort or heat stress • Adaptable design for subsequent retrofit; use standardised interfaces and protocols to make subsequent retrofit practicable; • Energy efficiency measures for buildings • Modelling of overheating and cooling; sophisticated modelling and integration of climate projections into both urban and building design; availability of weather data projections for building design
		Urban heat island effect exacerbating high temperatures			• Innovative planning and urban design /redesign of cities and provision of green infrastructure (green roofs, develop networks of open space, woodlands, parks and other natural areas) to mitigate urban heat island effect and to provide access to shaded outdoor spaces; • Understanding microclimatic impacts on built environment; tools to model and interpret the impact of local climate in urban areas; • Understanding the impact of urban heat island effect on energy demand • Innovative use of underground space
Rising sea levels		Increased risk of inundation from the rising sea levels and coastal erosion			• Prevent unnecessary new development in areas at high risk • Reduce threat of coastal erosion through flood defences • Develop long term plans to manage coastal protection; dilemma of protecting the current development versus letting nature take its course • Flood risk assessment and modelling; vulnerability mapping;
Flooding		Increased risk of flooding from rivers			• Prevent unnecessary new development in areas at high risk • Develop long term plans to manage the risks of flooding • Provide flood defences and limit risk in flood-prone areas for critical infrastructure such as electricity sub-stations • Upgrade drainage systems for transport infrastructure • Improve water resistance of building design to protect water entry points: air brick covers, door guards, non-return valves in drains preventing sewage backing up into buildings; water resistant materials
Heavy prolonged rainfall		Increased risk of flooding from excessive surface runoff in built-up areas ('soil sealing') during wetter winters			• Manage waste water and surface water run-off to protect public health • Re-design cities with better landscape and surface design (permeable surfaces) to collect storm water; provide 'green infrastructure' • Provide appropriate drainage / sewerage • Design new developments to include measures improving surface runoff; include sustainable drainage systems as part of new building design; • Improve water resilience of buildings by making them easier to repair and dry out • Revise peak flow assumptions for drainage systems
Droughts		Increased risk of droughts and water supply constraints during drier summers			• Develop a better understanding of the risk of water supply-demand deficits in the UK and its implications for public water supply and food production • Encourage efficient use of water in homes and businesses through measures stabilising and decreasing per capita water consumption, particularly in areas prone to water scarcity • Provide drought resilient planting and water retention as part of sustainable drainage • Demand management and strategic planning of water supply • Water efficiency and water saving systems (urinals, taps, showers; rainwater harvesting systems; grey / black water recycling, water storage in basements) • Develop a programme of small and larger scale field testing of water re-use and recycling technologies for residential buildings e.g. delivery of two grades of water into buildings • Understand trade off between cleaning wastewater to higher standards and energy required to do so in light of commitments to reduce carbon
High winds		Extreme weather conditions causing increased damage			• Design for extreme loads • Increase wind resistance for buildings
Stability and moisture of soil		Soil heave and subsidence increasing ground movements and destabilisation of buildings and infrastructure			• Design for subsidence and ground movements • Model future soil condition and its impact on cables, pipes and underground infrastructure

11 Theme 4: Resilience, safety, security, hazards

	Main Challenges	Impact	Urgency	Example Responses
Resilience, safety, security and hazards				
Uncertainty of future requirements and conditions	Design semi-permanent assets with enough flexibility to meet future and changing requirements			• Design and construct infrastructure to be flexible, adaptable, easily upgraded or downgraded. • Design buildings flexibly, initially for one form of occupation, to be converted readily to alternative uses • Design urban systems for resilience and adaptability; adaptable buildings • Explore opportunities for incorporating biological processes and developments in nanotechnology in the design and construction of dynamic or responsive structures
Increasing reliance on continuous availability of infrastructure services	Ensure urban resilience and infrastructure resilience to climate change			• Adapt existing infrastructure to cope with changing climate patterns • Gather quantitative evidence of the impacts of climate change in the built environment; understand possible adaptation options in the built environment and its infrastructure • Review design criteria and develop new guidance in response to climate change • Improve resilience of operational sites and supply chains through diversification of supply chains • Improve capability in operational risk management • Develop new methodologies and practical decision making tools for assessment of adaptation options • Develop robust risk-based adaptation strategies for use by decision makers and policy makers • Integrate smart technology into networks, distributed power systems and energy storage to improve resilience • Transport planning, risk management and modelling for assessment of transport adaptation needs
Interdependencies of infrastructure networks	Increasingly inter-dependent infrastructure networks leading to reduced resilience and increased vulnerability to hazards and systemic failure			• Assess systemic risks and understand how failure in one area can result in problems in inter-connected systems. • Improve the modelling of infrastructure systems and increase our understanding of the systematic interaction of infrastructure sectors • Identify critical interdependencies that will impact on infrastructure investment needs • Understand interdependencies between sectors (e.g. water is essential for cooling power stations; energy is essential for heating, ventilation and air conditioning) and opportunities for innovation and collaborative planning and design of measures • Identify major cross-sector engineering challenges and decisions in future infrastructure • ICT sector contribution to risk management and control (e.g. monitoring vulnerable structures in transport networks; power system control) • Understand how widespread use of IT and the move to electrification affects risk of critical failure
Ageing infrastructure assets	Maintain transport, water and waste systems in the face of growing demand and ageing assets in developed countries			• Maintain transport, water and waste systems • Renewal, rehabilitation, replacement, modernisation and sustainable management of transport and utilities infrastructure networks to combat the effects of ageing and climate change • Understand the implication of longevity / design life of built assets for maintenance strategy, capital investment the value of the stock and reliability, to make informed decisions when to build for long or short design life and when to retain or replace built assets • Develop methods, materials and techniques for cost effective maintenance and life extension of existing transport infrastructure • Facilitate the integration of infrastructure planning and management with spatial planning and other fields • Examine the interactive influence of scale (global, national, regional, local) for decisions within and between infrastructure sectors and between public and private led initiatives (public transport vs private; local power generation vs national grid; catchment management vs national water distribution) • Identify opportunities for multi-purpose operations such as water treatment with combined heat and power • Develop regimes for routine inspection and maintenance for infrastructure • Apply ICT to infrastructure networks to aid their planning, delivery and maintenance; collect real-time data on infrastructure overload, environmental performance and safety to inform infrastructure maintenance and upgrade decisions; understand potential of instrumentation and IT deployment for whole-life monitoring of infrastructure projects beyond the construction works stage • Develop and use innovative durable materials in transport
Increasing security and safety concerns	Improve security of the built environment			• Measures to design out crime • Design safer places
	Culture of health & safety and liability			
	Provide secure supply of energy, water and transport			• Determine how to deliver security of utiliy supply with minimum overhead cost • Improve reliability and resilience of infrastructure networks • Improve the use of IT infrastructure monitoring, emergency warning, and surveillance
Increased complexity and variety of hazards	Increase community resilience to impacts of natural and man-made hazards (malicious attacks and natural disasters)			• Disaster response trends and disaster management • Improve emergency response to hazards particularly in places where there are limits to climate adaptation • Explore response options in the event of critical system failure including a better understanding of human reactions • Examine interaction between maintaining standards of hazard management and maximising opportunities for habitat creation and maintenance of biodiversity

12 Theme 5: Climate change mitigation

	Main Challenges	Impact	Urgency	Example Responses
Climate change mitigation: Energy generation and supply				
Energy security	Ensure long term energy security and reduce long-term UK dependence on imported fossil fuels			• Revolution in energy generation mix (diversification of sources and reliance of on-site energy generation) • Greater energy interconnection with Europe and Ireland • Further private sector investment in liquefied natural gas terminals and gas storage to provide resilient gas supplies • Understand trade-off between security of energy supply and reduction in CO2 emissions
	Moderate demand at peak times and preserve supply and demand balance			• Cater for intermittent character of renewable electricity generation through energy storage solutions (hydro and pumped storage schemes) and adaptation of existing plants to play supportive role • Smart grid and smart meter technology to make homes and businesses intelligent parts of electricity network enabling demand management
Decarbonisation of the power sector	Shift from conventional fossil fuel energy generation towards new technologies (both large scale and on-site in buildings) - Renewable - Nuclear - CCS			• **Wind:** world-leading array of offshore wind turbines, major investment in DC cables and manufacturing facilities at port sites and private sector investment in onshore wind turbines; new energy storage and load balancing technologies are required) • **Solar**: • **Tidal:** economics depend on discount rate; potentially has environmental impacts • **Biomass:** the role of appropriate use of bioenergy needs to be determined, where transformation losses are lower, e.g. heat, or alternative renewable sources are less likely to be available such as in aviation; expansion of technologies such as anaerobic digestion to produce heating gas from sewage, industrial, commercial, residential and farm waste • **Nuclear:** is cost competitive; main constraints are likely to be the feasible build rate which is limited by supply of technically competent nuclear specialists and demanding regulatory frameworks; issue is long-term sustainability of nuclear waste storage and affordable ways of dealing with the nuclear contamination legacy • **CCS:** will always be expensive, but needs to be developed rapidly through large scale demonstrations; technical challenges for design of the power system related to introduction of low-carbon electricity based technologies • Continue research into wind, wave, tidal, solar, with emphasis on transformational improvements in components and systems such as efficiency of offshore wind turbine foundations, materials and reliability of components, ocean current and wave converter devices • Use less carbon intensive fuels such as solid recovered fuels • Renewable heat installations in homes • Alternative energy / heat technologies in buildings such as photo-voltaic, heat pumps, fuel cells;
Efficiency of energy distribution, use and recovery	Increase use of on-site energy generation and recovery			• Domestic and community-based decentralised electricity generation; distributed energy and heat • Understand how to provide more efficient and cheaper systems through solutions such as systems that cover multiple buildings and building types (community solutions), economies of scale, product and process innovation • Understand how best to utilise combination of energy solutions e.g. combination of centralised and distributed energy solutions for housing developments; optimise energy supply solutions for buildings and districts • Develop robust and accurate modelling to understand implications of low-carbon heat and energy solutions (heat pumps, biomass boilers, community CHP, solar and thermal installation) alongside energy conservation measures • Recover low grade heat, for example from waste hot water • Develop products related to power distribution • How to lower the cost of the wide range of options for micro-generation of electricity
	Optimise engineering systems within buildings using IT advancements (Smart buildings)			• Smart building energy use metering and control • Buildings operating interactively with people, learning user behaviour and preferences, optimise the use of power and heating • Develop products for lighting (more sophisticated lighting controls, DC lighting; raised lighting levels without additional energy consumption) • Develop products for wiring and controls (whole house systems, and the interplay between technology and consumer behaviour; switching appliances on and off; controlling speed of fans and motors; plug in display wiring) • Research into systems-level approaches to managing and operating buildings to reduce CO2 emissions and optimise energy use • Energy efficient cars synchronised with reductions in the carbon intensity of electricity generation

		Main Challenges	Impact	Urgency	Example Responses
Climate change mitigation: Carbon in project design					
Carbon in project appraisal		Consider carbon efficiency at concept stage and factor whole-life carbon into appraisal into feasibility studies			• Factor whole-life (operational + embodied) CO2 into project appraisal and feasibility studies • Give greater prominence to CO2 reduction in the Environmental Impact Assessment • Prioritise carbon reduction of whole-life carbon emissions in design and construction of infrastructure • Understand whether carbon reduction targets are achieved on current infrastructure projects • Make key decisions related to carbon reduction at the concept stage, using integrated approach to the evaluation of options and performance (Carbon consideration currently takes place by choosing 'least bad' construction option) • Develop models to support the evaluation of optimal infrastructure solutions at concept in terms of whole-life carbon. • Envisage optimal conceptual infrastructure solutions facilitating carbon reduction (e.g. designing flatter roads) • Develop quantifiable measures for the assessment of the sustainability of infrastructure at concept stage.
		Balance embodied / capital and operational carbon emission of construction projects			• Understand 'where is carbon?' How energy is consumed in different building types, in different forms of construction, for different building types? What are the benchmarks? • Challenge current design and construction practices and assess whether design codes or regulations need to change where they perversely increase capital carbon without proportionate benefits • Avoid situations where low operational emissions are due to uneconomically raised embodied emissions • Set appropriate lifespan of projects: What lifetime of project should be assumed? What assumptions should be made about treatment of material at the 'end of life' • Gather data for typical infrastructure projects across the sectors, comparing capital and operational carbon, understand amount of carbon used in each of the infrastructure areas, seek potential for balancing cap-carb and op-carb at concept stage and seek potential for whole-life carbon reduction • Develop practical, workable definition of zero-carbon
		Develop unified approach to carbon accounting (methods, discount rate, carbon price)			• Develop a standard method for measuring embodied / capital carbon for use as a design tool and for the purpose of scheme appraisal. • Agree schedule of data needs, method and programme for collecting, analysing and disseminating carbon accounting data (especially whole-life accounting) for the transition to low-CO2 built environment • Understand how much lower should discount rate for carbon in consideration of infrastructure project should than for other types of construction projects due to long life of infrastructure assets • Develop methodology for rigorous whole-life carbon estimation and include it in codes and standards (unified approach to carbon accounting in line with European Standards) • Develop unified framework and boundaries for analysis underpinning tools and methodologies used for carbon assessment to avoid conflicting advice given by those currently available and for results to become transferrable • Review carbon accounting principles of HM Treasury
Carbon in construction supply chain		Reduce embodied carbon of products and materials used in construction			• Decarbonise business of companies in the wider construction industry • Set up a construction-specific accreditation scheme for companies committed to improving their environmental credentials • Gather reliable data about materials and product footprints, product life and carbon traded by suppliers • Develop clear labelling of construction products with verified data on their embodied carbon, energy performance and environmental standards • Develop new low carbon products and services and logistics to deliver them at scale • Change the process of material production to reduce energy use, apply new technologies to reduce emissions (e.g. CCS in cement and steel) • Re-use and re-cycle materials. Investigate the opportunities and barriers for the use of recycled elements, and use of waste or by-products like steel slag • Develop products related to recycling, and low carbon material handling options and construction waste • Drive local production and use to reduce carbon footprint • Gather reliable data about sequestered carbon in timber
Carbon reductions versus wider performance		Compromise between the wider performance requirements and carbon reductions			• Weighing of carbon reduction and energy efficiency against other purposes for which buildings are commissioned • Understand where margins included in infrastructure design (e.g. safety factors) are leading to unnecessary material use and over-engineering; • Adopt new safety paradigm with increased requirement for testing and rigorous failure mode analysis but increased tolerance for damage due to extreme events • Understand the opportunities for carbon reduction through better engineering (better, tighter design, engineering standards, specifications and measurement)

		Main Challenges	Impact	Urgency	Example Responses
Climate change mitigation: Decarbonising economy through built environment					
Low-carbon infrastructure		Delivery of infrastructure that supports the creation of a low carbon economy			• Develop broad vision, long-term planning and policy for future shape of infrastructure needed, to meet carbon targets and long term infrastructure policy for carbon reduction • Establish and use a common set of planning assumptions, e.g. economic growth forecasts, population growth forecasts, impacts of climate change • Change planning and delivery of infrastructure to adopt a systems approach to carbon reduction from integrated infrastructure solutions (e.g. road on top of embankment) • **Transport** Understand trade-off between reduction in transport CO2 impacts and freedom of dispersed travel choices. Decarbonisation of the car fleet (improving fuel efficiency of conventional engines and increased use of sustainable first generation biofuels, progressive introduction of new technologies such as electric cars, plug in hybrids and hydrogen vehicles, and second generation biofuels). Investments in recharging infrastructure for electric vehicles. Improvements in battery technologies. Apply demand side measures - changed driver behaviour, modal shift, better journey planning. Understand the optimum use and implications of energy regeneration in transport and its applications. • **Heat sector** Shift to renewable heat generation: increased use of biomass in boilers and CHP, air exchange and ground source heat pumps, and modern electric storage heating • **Waste** Divert biodegradable waste from landfill to prevent methane generation; energy recovery from waste where possible with combined heat and power • **Water** Improve understanding of the links between the water treatment process and carbon recycling
Low-carbon buildings		Improve energy efficiency of buildings (commercial + domestic) through measures and products			• Improved passive techniques, insulation, glazing, HVAC systems, (details below) • Implement sealing buildings / sealing with degree of air tightness; understand potential detrimental effects for air quality, occupant comfort and consequences to health
		Lack of market demand (commercial + domestic) for low-carbon new-build and retrofit, hindering supply chain innovation in low-carbon products and services			• Stimulate consumer demand through a framework of incentives, interventions, via carbon price, taxes, subsidies; and regulation • Understand appropriateness / feasibility of different fiscal incentives to overcome inertia and low customer awareness of energy efficiency in domestic buildings • Understand how incentives interact with decisions made by owner, occupier, property investors and tenants to build low-CO2 buildings and use them more efficiently. • Investigate willingness to pay - understand how the market values low-carbon buildings (or energy efficiency in general), today and in the interest of future proofing; evidence of rental / sale value attached to energy efficiency • Introduce minimum standards for existing buildings by mandating Energy Performance Certificate ratings for all non-domestic buildings • Develop practical phased packages for domestic building energy efficiency improvements; carry out technical analysis of current house types and devise appropriate treatments for different forms of construction of existing housing • Provide industry with confidence that market failure will be addressed to provide incentives for carbon reduction
		Preference to minimise upfront cost resulting in increase in whole-life energy performance			• Understand trade-offs between capital expenditure and whole-life building energy consumption; • Estimation of upfront and whole life costs and of the impact of quality on building performance.
		Lack of clear responsibility for energy efficiency of non-domestic buildings.			• New mechanisms for alignment of costs and benefits between landlords and tenants; leases to require both parties to take responsibility for energy efficiency • Management of energy use in buildings (currently in residential and commercial sectors energy costs are small proportion of total costs) • Need for policy requirement for landlords and tenants to agree an Energy Management Plan for their buildings to accompany Display Energy Certificate
		Close gap between predicted and actual performance of buildings: *Improved modelling*			• Develop methodologies for testing the anticipated performance of design propositions capable of showing benefits of application of new products; currently calculation tools (SAP, S-BEM) are based on established systems - new products and systems are not incorporated. • Improve skills in building engineering physics and performance modelling, in particular modelling physical attributes such as solar gain and cooling loads • Understand how new homes will perform, especially with inter-related issues of summer overheating, air-tightness and indoor air quality • Develop more rigorous estimates of energy performance based on real situations and incorporate this into models. • Ongoing monitoring of new-build and retrofitted properties to assess the actual performance of measures against modelled predictions
		Close gap between predicted and actual performance of buildings: *Monitoring*			• Monitor post-occupancy performance as a formal structured part of procurement process as a verification of predicted value / design criteria • Develop building rating systems with clear focus on energy, that measure both the design performance of building and its actual operational use • Gather data on the carbon performance of buildings and understand level of non-compliance and its impact on carbon emissions; review compliance mechanisms • Measure and display building energy consumption; use Display Energy Certificate as benchmark and to create awareness; publicise energy data contained within DEC; review benchmarks used to calculate DEC ratings to ensure they are consistent and robust and effectively differentiate on energy performance of buildings of different types • Consistent, comparable protocols and formats of building performance data • Establish how exactly zero-carbon performance is to be defined and how far the use of renewable energy is to be taken into account in the assessment of performance

Passive design Passive design optimising heat / cooling flows making best use of external climate; increase use of passive techniques; shading, high thermal mass designs, increased cooling loads, right lightweight or heavyweight thermal fabric, free cooling, slab cooling, evaporative cooling, ground cooling, chilled ceiling beams, cool roofs reflecting sunlight; 'Smart coatings' reflecting heat; improved air tightness, Fabric products (excluding glazing) increasing air-tightness; reducing cold bridging such as thermal break wall ties;

Insulation Improved insulation (including loft wall insulation, phase change insulation materials), Utra-high performance easily applied isolative coating for solid walls, internal and external, system solutions for apartment blocks and engineered solutions that can be deployed in high volumes with limited failures; New types of insulation materials, particularly for solid wall retrofit, and heat storage technologies to take advantage of solar-thermal heat opportunities; Increasing insulation performance, including carbon negative walling materials and products for "hard to treat" buildings (e.g. aesthetically acceptable external insulation). Gel insurants; Internal clay blocks

Glazing double / triple window glazing, Products for glazing (effective shading, energy efficient windows such as passivhaus standard; Specialist glass and coatings);

HVAC Low-carbon HVAC / energy systems / controllable ventilation; natural ventilation; heat recovery and microgeneration systems; adequate sizing of HVAC plant and equipment in buildings; Products for heating / hot water that provide comfort whilst reducing heating load (or not adding to peak load), in combination with the right thermal fabric; Energy efficient operation of buildings and machinery to reduce heat gain in buildings; Use of more efficient appliances, turning appliances off and using less air conditioning

13 Theme 6: Value and wellbeing

	Main Challenges	Impact	Urgency	Example Responses
Value and wellbeing				
Cost versus value	Tradition of procurement for minimisation of cost with minimal attention to value created over the lifetime of an asset Clients struggling to articulate what value means to them			• Adopt broader vision of the industry embracing the whole, complex picture of how people can interact sustainably with the environment to maximise health, wealth and happiness. • Understand impact of construction on quality of life, wider community and role of built environment in creating sustainable communities. • Convert criteria for value into standards, outcome-based specifications and clear performance criteria • Set clear criteria for the way a built asset delivers value in service; use benchmarking and feedback from previous projects • Develop a vocabulary of value, a common language for discussion of the subject in the built environment, this should include a dictionary of 'intangibles' and ways of measuring them. • Create a toolset to support customer business case-making on a value basis; this would include tools for estates professionals to value intangibles, probably drawing on brand valuation techniques.
	Achieve good design Built environment providing value to end-users, supporting productivity and wellbeing; Buildings integrated with their environment and neighbourhood			• Projects fit for purpose (client and occupant needs), resource efficient, sustainable, resilient, adaptable and attractive, contributing to physical and mental health, wellbeing, social relationships, reduced crime, higher productivity • Focus on the customer providing a product that the customer wants at a price which reflects its value • Greater need to understand customer business activity and align offer to client expectations • Understand the impact of good / bad design on the built environment and on the value of built assets in relation to both new works and the existing stock. • Understand relationships between buildings, infrastructure and human wellbeing; interaction of people with environment and buildings • Understand relationship between achieving sustainability / good design and competitiveness / productivity issues • Create a model of the built environment as a component of the whole UK economy, integrating property and facility management with construction. • Study value in the urban context, revealing the links between quality in the public realm and demand for healthcare, social services and justice system services; the positive effects of landmark quality projects should also be studied. • Carry out 'bottom-up' studies of value creation and destruction in the key sectors of healthcare, education and office work, relating benefits to sacrifices • Address interaction of civil engineering with communities and the way in which societal aspirations will influence future civil engineering projects • Understand diversity in communities; multiculturalism; symbolic and social meaning of built environment • Positive engagement of local communities in construction projects - explore opportunities to better involve communities in the design and construction process • Optimise indoor environment for occupant health providing a degree of energy autonomy through daylighting, high insulation, renewable energy harvesting or on-site generation • Provide floorplates which support socially effective circulation, the most useful organisational patterns and amenities to optimise staff interaction
	Integrate planning, design, construction and operation of built facilities.			• Understand how value is created over the whole lifecycle of an asset and cost arising from requirement for life-long maintenance or future upgrade • Designing for ease of security, cleaning and maintenance access • Design projecting an image which supports the occupier's and owner's corporate responsibility stances

14 Theme 7: Industry

	Main Challenges	Impact	Urgency	Example Responses
Industry: Capability				
Reputation and status	Low profile and poor industry brand. Failing to attract enough talented people into the industry			• Need to improve the image of the industry to attract the right calibre of employees • Adopt and promote a broader vision of the industry based on its contribution to quality of life and creating sustainable communities and integrated neighbourhoods • Improve image through corporate social responsibility • Leadership to communicate vision and engage employees to think about the value of their input
Skills	Skills shortage - Dropping numbers of engineering students - New skills required in response to new challenges and modernised industry - recession-related downsizing			• Build skills and capacity required to support modernised industry and in response to current drivers such as CO2 agenda (changes to construction methods, from design and planning of new buildings and infrastructure to the materials, products, processes in use, and maintenance and management of the existing assets) • Develop a single strategic view on future skills needs in the light of changing skills landscape and collaboration and integration of professions, trades and products and materials industry • Assess the industry skills and ability to deliver; establish changes required to education and to professional practice to allow transition to low-carbon economy
	Failure to develop talent within the industry and departure of talent both overseas and to other industries.			• Improve graduate development programmes and leadership training at all levels of the industry, particularly for junior leaders and supervisors • Set out the learning and skills agenda for professionals in all areas of the built environment, to inform employers, educators and the relevant Learning and Skills Councils
	Fragmentation of disciplines and narrow degree courses prevent holistic thinking and perpetuate fragmented industry model			• Facilitate high-profile generalist construction qualification • Develop students to think holistically about how we create integrated built asset solutions,
Leadership	Lack of a clear mission, purpose or vision			• Formulate mission based on a strong ethical stance, for the contribution industry makes to society • Promote how the built environment contributes to the UK's long-term prosperity and to achieving a sustainable low carbon economy • Supply side leadership in demonstrating added value; demonstrate how it can create additional economic, social and environmental value through innovation, collaboration and integrated working
	Fragmentation of industry structure and lack of unified voice of the industry - too many industry bodies and sector skills councils impeding a broader and strategic understanding of built environment and cooperation the Government.			• Form a single, coherent voice for the industry to prevent dilution of key messages from different industry bodies or contradictory messages • Unified voice of the industry - Close cooperation between Government and the Industry • Industry to inform government policy by practical propositions and by full knowledge of the capacity of the industry
	Improve construction project management capability			• Develop future generation of leaders • Improve management and supervisory skills at all levels

New skills and competencies required: Design management; Production planning, assembly and installation management; Specialist project finance; Specialist legal advice; Risk assessment and management; Safety management; Supply chain management; Procurement and logistics; Instrumentation and control systems; Non-destructive testing; Facilities management; Energy management; Water management; Building physic; materials science; contaminated land engineering; geotechnical engineering; structural engineering; facade engineering and design; mechanical and electrical engineering; heating, ventilation and air-conditioning; manufacturing engineering; wind, seismic and vibration engineering; fire engineering; lighting design; acoustical engineering; simulation and modelling; computational fluid dynamics; IT systems and data management; documentation control; machinery operation and maintenance; Environmental planning; Transport planning; Space planning, syntax and changing working patterns; business analysis; dynamics and complex systems analysis; building economics and life-cycle analysis; Team building co-locating and concurrent engineering; partnering and supply chain management; interdisciplinary skills to integrate engineering and social science expertise; Understanding users and regulatory frameworks; Delivery if integrated products and services; Research and up-skilling required in solid wall insulation, renewable power / micro-generation (PV, Solar, Biomass), ventilation, controls and integrated systems, lighting systems, general building and fabric to enable new products coming to market (e.g. recoverable heating technologies); Up-skilling the supply chain in cavities and lofts insulation, windows, boilers and heating (transition from gas to electric)

	Main Challenges	Impact	Urgency	Example Responses
Industry: Procurement				
Modernisation	Improve product development Use standardised components and pre-assembly rather than bespoke design			• Encourage standardisation rather than bespoke design setting clear criteria for asset performance • Design projects for ease of construction making max use of standard components and processes • Offsite fabrication, increased use of pre-manufactured components, intelligent use of standardisation and mass customisation • Research into prefabrication and scope for prefabricated solutions where there is a need for large number of similar facilities for formally independent clients but in the same policy area
Integrated procurement	Lack of an integrated project delivery resulting in sub-optimal solutions Clients unaware of the potential value that integrated supply chains (designer, contractor and facilities management) can bring, and fail to engage them.			• Consider facilities management and operational integration at the design stage • Early involvement of supply chain to deliver best possible solutions in terms of design, buildability, environmental performance and sustainable development • Clients brief to concentrate on required performance and outcome; designers and constructors work together to develop an integrated solution that best meets the required outcome • Early involvement of contractor: contractors engage key members of their supply chain in the design process where their contribution creates value • Value for money and competitive tension are maintained by effective price benchmarking and cost targeting, by knowing what projects should cost, rather than through lump sum tenders based on inadequate documentation; • Improve understanding of construction process re-engineering, industry performance improvement, integration of technology / management • Regulation in infrastructure sector produced good examples of integration that is sought more widely in construction • Increase integration of supply chain from design to operation; define gains from an integrated supply chain
	Lack of stable supply chain			• Working with fewer suppliers in a more settled supply chain through creation of frameworks • Engage supply chains on a serial order basis of sufficient scale and duration to incentivise research and innovation around a standardised (or mass customised) product • More business drivers for supply chain to improve and deliver meaningful change. Supply chain prefers stable unexciting returns and sees changes as 'too difficult'
Collaborative procurement	Adversarial working practices and cultural resistance against partnering due to issues of trust and respect Contractors' mindset is to procure in order to pass risk down the supply chain, rather than to draw up opportunities to create value by working as an integrated team			• Partnering supply chain (to drive innovation and performance improvement with opportunity to share reward) • Adopt new business models that promote collaboration e.g. use of integrated project insurance • Include protection mechanisms in contracts to facilitate culture change. Define how client's position would be protected against cost increases that could result from the lack of competitive tension; define how architects position can be protected against subordinating principles of good design to ease an economy of construction that could result from tier one contractors' excessive influence • Understand enablers of culture change • Develop concepts for value-based reward of supply side participants, intended to align motives with those of customers, releasing reward when value targets are met or exceeded.
	Many forms of contract and bespoke contracts			• Use of standard forms of contract; use of standard prequalificaiton form; adjust contracts to suit modern industry practices • Complete families of interlocking contract documents should be prepared and used • Lists of consultants and contractors should be kept and developed into quality registers
Client	Client teams with insufficient skills to drive innovative procurement			• Industry to define and clients to develop core skills in project delivery • Governance, appropriate skills and clear accountability for commissioning and delivery
	Lack of client leadership towards better construction			• The low impact of construction costs and outcomes on the client's business case makes construction low-priority to client's in some sectors • Client leadership required in adopting value-based rather than cost-based procurement (competitive tendering should be replaced with long term relationships based on clear measurement of performance and sustained improvements in quality and efficiency) • Government as client's leadership in setting example. Reform of public procurement through Government's Construction Strategy • Clients to reward suppliers who can deliver long-term sustainable solutions

		Main Challenges	Impact	Urgency	Example Responses
Industry: Performance					
Quality		Low quality of final product			• Incentives for quality; penalties for poor quality • Provide incentive to raise quality standards through PFIs where contractor has continued interest in the operation of the asset • Remunerate contractors in a way that incentivises them to deliver good quality construction on time and to budget • New arrangements for design review and construction to incentivize good quality and impose penalties for poor quality housing • Deploy benchmarking and continuous improvement
Predictability		Improve time and cost predictability			• Improve production and logistics of construction components to eliminate waste and ensure timely delivery of products • Client business models focused on short-term gain, • Dissatisfied clients increase customer focus
Cost		Reduce whole-life project cost (construction cost one of the highest in Europe)			• Improve UK planning system to bring down construction cost, improve quality of data to inform decision taking, initiate programmes to look at cross-sectoral interdependencies, resilience and engineering innovation that could drive the cost down • Simplify regulatory environment • Improve efficiency of procurement especially in infrastructure - the widespread growth of partnering and subsequently collaborative working could achieve 30% cost reduction within five years • Test whether alternative approaches to procurement of integrated teams can deliver zero-carbon buildings for no more than those built only to Building Regulations?
Productivity / efficiency		Eliminate waste, inefficiency and over specification			• More time given to planning before construction (getting construction sequence right, risk assessment, management of supplies) • Process improvement, lean thinking, value engineering • Adopt modern methods of construction • Eliminate frequent change and design variations - impose design freeze at the start of the project and rigorously adhere to it. • Apply waste hierarchy: reduce amount of waste produced, maximise reuse and recycling and recover energy from residual waste, landfill used as a last resort • Reduction of construction, demolition and excavation waste to landfill • Integrated teams, collaborative working through BIM
		Utilise IT as an enabler of better performance and improve adoption of IT in the construction industry			• Adopt BIM to reduce error and unnecessary design variations, cut out layers of waste, and reduce cost of information exchange in the supply chain • Develop skills and capabilities in BIM, and standard (compatible) systems / interface control and protocols • Identify when use of BIM is appropriate in terms of the type or scale of project, what are the barriers to widespread take up, how to avoid chaos in virtual teams and develop an outline protocol for future ways of working • Identify trial projects to achieve delivery via 3D fully collaborative BIM • Improve understanding of: Process integration using IT, IT systems (embedded systems, ubiquitous computing, e-business), Simulation and virtual reality, Facilities management and facility automation
		Improve technical and functional performance of construction workers			• More productive and engaged construction sector workforce • Employment, skills and training issues and on Improving Safety and Security within the Construction Sector

A1 References

This document includes two tables listing key documents reviewed as part of the project:

1) The first table lists Construction Sector Reviews and similar documents reviewed to identify **construction sector challenges**
2) The second table lists Research Roadmaps and similar documents reviewed to identify **key research themes in the construction sector**

Ref	Title	Author / Body	Date	Pages	Scope
01	Low Carbon Construction – final report	Construction Innovation & Growth Team	2010	231	Detail
01a	Low Carbon Construction - executive summary	Construction Innovation & Growth Team	2010	24	Detail
02	Government response to Low Carbon IGT	Government	2011	85	Detail
03	National Infrastructure Plan	HM Treasury Infrastructure UK	2010	52	Detail
04	Rethinking construction innovation and research: a Review of Government R&D Policies and Practices	Fairclough report	2002	50	Detail
04a	Rethinking construction innovation and research -summary	IStructE	2001	1	Detail
04b	Never Waste a Good Crisis - A Review of Progress since Rethinking Construction	Constructing Excellence	2009	32	Overview
05	Building a low-carbon economy - full report	Committee on Climate Change	2008	511	Overview
05a	Building a low-carbon economy – exec summary	Committee on Climate Change	2008	25	Detail
05b	Building a low-carbon economy – key messages	Committee on Climate Change	2008	12	Detail
06	Constructing the Team	Latham review	1994	135	Overview
07	The Social and Economic Value of Construction	Pearce review	2003	97	Overview
08	Rethinking Construction	Eagan	1998	43	Overview
08a	Rethinking Construction 2002	Department of Trade and Industry	2002	24	Overview
09	Accelerating Change	Strategic Forum for Construction chaired by Egan	2002	44	Overview
10	Changing to Compete - Review of Productivity and Skills in UK Engineering Construction	Gibson review - Department for Business Innovation and Skills	2009	44	Overview
11	The UK Low Carbon Transition Plan: national strategy for climate and energy	Department of Energy and Climate Change	2009	220	Overview

Ref	Title	Author / Body	Date	Pages	Scope
12	Zero Carbon Britain 2030 Energy Strategy	Centre for Alternative Technology	2010	384	Overview
13	State of the Nation - Infrastructure	Institution of Civil Engineers	2010	24	Overview for now
14	State of the Nation - Waste and Resource Management	Institution of Civil Engineers	2011	20	Overview for now
15	State of the Nation: Capacity and Skills	Institution of Civil Engineers	2008	16	Overview for now
16	Progressing UK Energy Research for a Coherent Structure with Impact	Report of the International Panel for the RCUK Review of Energy	2010	72	Overview
17	Meeting Carbon Budgets: ensuring a low-carbon recovery	Committee on Climate Change	2010	168	Overview
17a	Meeting Carbon Budget: ensuring a low-carbon recovery – exec summary	Committee on Climate Change	2010	34	Detail
18	Government Construction Strategy		2011	43	Detail
19	Building Information Modelling (BIM) Strategy Paper for the Government Construction Client Group	BIM Industry Working Group	2011	107	Overview
20	Strategy for Sustainable Construction	Strategic Forum for Construction	2008	64	Detail
20a	Strategy for Sustainable Construction – Progress Report	Strategic Forum for Construction	2009	71	Detail
20b	Carbon: Reducing carbon of the construction process and action plan	Strategic Forum for Construction and Carbon Trust	2010	65	Overview
21	Infrastructure: Supporting the Future (only hardcopy; no link)	EPSRC	2011	6	Overview
22	Strategy for national infrastructure	HM Treasury	2010	48	Overview
23	A national infrastructure for the 21st century	Council for Science and Technology	2009	60	Overview
24	Sustainable Competitiveness of the Construction Sector	Directorate-General Enterprise & Industry	2011	286	Detail
24a	Sustainable Competitiveness of the Construction Sector - public consultation survey	Directorate-General Enterprise & Industry	2011	22	Detail
25a	Opportunities for UK Business from Climate Change Adaptation – Chapter 1 – Exec Summary	Defra Link to project site	2010	24	Detail
25b	Opportunities for UK Business from Climate Change Adaptation – Chapter 2- Built Environment	Defra	2010	24	Detail
25c	Opportunities for UK Business from Climate Change Adaptation – Chapter 3- Water	Defra	2010	21	Overview
25d	Opportunities for UK Business from Climate Change Adaptation – Chapter 4- Energy	Defra	2010	18	Overview

Ref	Title	Author / Body	Date	Pages	Scope
25e	Opportunities for UK Business from Climate Change Adaptation – Chapter 5- Transport	Defra	2010	12	Overview
26	International Dimensions of Climate Change	Government Office for Science	2011	129	Overview
27	The future for architects	RIBA	2010?	24	Overview
28	RIBA Constructive Change - strategic industry study into the future of the Architects	RIBA	2005	19	Overview
29	Engineering a Low Carbon Built Environment	Royal Academy of Engineering	2010	52	Overview
30	Hidden Innovation AppB-Construction	National Endowment for Science, Technology and the Arts (NESTA)	2007	5	Overview
31	Innovation in Construction Services	Department for Business Enterprise and Regulatory Reform	2008	25	Overview
32	Measuring the Competitiveness of the UK Construction Industry	DTI	2004	61	Overview
33	Infrastructure Cost Review	Infrastructure UK	2011	36	Detail
34	A strategy for Materials	Materials Innovation & Growth Team	2006	26	Overview
35	Global Construction 2020 – exec summary	PwC and Global Construction Perspectives	2011	7	Detail
36	The real budget for research: an analysis of current levels of public funding for built environment research	Commission for Architecture and the Built Environment (CABE)	2004	12	Detail
37	Be valuable: A guide to creating value in the built environment	Constructing Excellence	2005	29	Overview
38	Achieving Excellence in Construction guide series (website link)	Office of Government Commerce	1999	many	Overview
39	Modernising Construction	National Audit Office	2001	105	Overview
39a	Modernising Construction –exec summary	National Audit Office	2001	14	Detail
40	Improving Public Services through Better Construction	National Audit Office	2005	87	Overview
40a	Improving Public Services through Better Construction – exec summary	National Audit Office	2005	19	Overview
41	The Review of Housebuilding Delivery	Callcutt Review	2007	236	Overview
41a	The Review of Housebuilding Delivery – exec summary	Callcutt Review	2007	4	Detail
41b	The Review of Housebuilding Delivery – recommendations	Callcutt Review	2007	5	Detail

Ref	Title	Author / Body	Date	Pages	Scope
42	Construction Commitments	Strategic Forum for Construction	2008	6	Overview
43a	Construction Matters Volume 1	Business and Enterprise Select Committee	2008	126	Overview
43b	Construction Matters Volume 2	Business and Enterprise Select Committee	2008	388	Overview
44	Equal Partners: Customer and supplier alignment in private sector construction	Business Vantage and Construction Clients Group	2008	44	Detail
45	Engineering to live within planetary boundaries: civil engineering research needs	ICE	2011	15	Detailed
46a	Powering our Lives: Sustainable Energy Management and the Built Environment: Final Report	Government Office for Science	2008	213	Overview
46b	Powering our Lives: Sustainable Energy Management and the Built Environment: Futures	Government Office for Science	2008	60	Overview
47	Procurement in the Construction Industry	Chartered Institute of Buildings (CIOB)	2010	16	Possible
48	Managing the Risk of Delayed Completion in the 21st Century -	Chartered Institute of Buildings (CIOB)	2008	55	Possible
49	Leadership in the construction industry	Chartered Institute of Buildings (CIOB)	2008	24	Possible
50	The impact of the ageing population on the construction industry	Chartered Institute of Buildings (CIOB)	?	24	Overview
51	Innovation in Construction - Ideas are the Currency of the Future	Chartered Institute of Buildings (CIOB)	2007	20	Overview
52	Anticipating Tomorrow: the Future of the European Construction Industry	European Construction Institute	2008	42	Detail
53	Future Generation of IT: Vision Planning Workshop Report	University of Salford, University of Loughborough and VTT	2009	28	Overview
54	Green Economy - Chapter "Buildings: Investing in Energy and Resource Efficiency"	UNEP	2011	44	Overview
55	CIB White Paper on IDDS - Integrated Design & Delivery Solutions	CIB	2010	21	Possible
56	Report on a Workshop: Technological Change and Rethinking Construction (only hardcopy; no link)	Laroch Associates / CRISP	2000	37	Possible
57	Construction for Sustainable Development - Research and Innovation Needs (only hardcopy; no link)	Joyce Moore, Fiona Gooch, Sarah-Jane Orr,	2000	69	Possible
58	Constructing the Future – Full Report (only hardcopy; no link)	Built Environment and Transport Panel Construction Associate Programme	2001	31	Possible
58a	Constructing the Future – Exec Summary (only hardcopy; no link)	Built Environment and Transport Panel	2001	8	Possible

Ref	Title	Author / Body	Date	Pages	Scope
		Construction Associate Programme			
59	Infrastructure Research Priorities (only hardcopy; no link)	ICE on behalf of the National Platform	2004	31	Possible
60	A Research Strategy for the Construction Industry (only hardcopy; no link)	?	2003	26	Possible
61	What kind of research and innovation strategy does UK construction need? (only hardcopy; no link)	ncrisp	2004	8	Possible
62	Sustainable Construction: Future R&I requirements. Report for the CRISP Sustainable Construction Theme Group Analysis of current position	CIRIA, BRE, Eclipse & Salford University	1999	18	Possible
63	Riding the rapids: Urban life in an age of complexity	Building Futures (CABE + RIBA)	2004	116	Overview
64	21 drivers for 21 century	Outsight consultancy	2008	20	Overview
65	Building for the Future: Sustainable construction and refurbishment on the government estate – Full report	National Audit Office	2007	43	Overview
65a	Building for the Future: Sustainable construction and refurbishment on the government estate – Executive summary	National Audit Office	2007	4	Detail

Roadmaps:

Ref	Title	Author / Body	Date	Pages	Scope
M01	Energy Efficient Buildings PPP Multi-annual Roadmap and longer term strategy	Ad-hoc Industrial Advisory Group, European Commission	2010	52	Detail
M01a	Research Priorities for the Definition of a Multi-Annual Roadmap and Longer Term Strategy	Ad-hoc Industrial Advisory Group, European Commission	2009	38	Detail
M02	Construction Resources and Waste roadmap	BRE	2008	44	Overview
M02a	Construction Resources and Waste roadmap – short guide	BRE	2008	8	Detail
M02b	Construction Resources and Waste roadmap - update	WRAP	2010	50	Detail
M03	Roadmap for a transformation of energy use in buildings	World Business Council for Sustainable Development	2009	1	Overview
M04	Towards a low carbon built environment, a roadmap for action	RICS	2009	88	Detail
M05	Roadmap for a Low-Carbon Economy by 2050	European Commission	2011	16	Detail
M06	The National Platform Strategic Research Agenda		?		Detail
M07	ICT and Automation Scoping Study	National Platform	?	35	Overview

Ref	Title	Author / Body	Date	Pages	Scope
M07a	ICTA Scoping Study Roadmaps	National Platform	?	5	Overview
M07b	ICTA Scoping Study Appendices	National Platform	?	45	Overview
M08	Client-orientated, knowledge-based construction process (CDA) Scoping Study	National Platform	?	56	Overview
M09	Reduced Resource Consumption in the Built Environment Construction industry Scoping Study	National Platform	?	72	Overview
M10	Strategic Research Agenda for the European Construction Sector	European Construction Technology Platform (ECTP)	2005	50	Overview
M11	The European Construction Technology Platform (ECTP) and a Vision 2030	European Construction Technology Platform (ECTP)	2005	32	Overview
M12	Cement Technology Roadmap: Carbon emissions reductions up to 2050	World Business Council for Sustainable Development	2009	36	Overview
M13	ICT for energy efficient buildings – ECTP workshop presentation	By Matti Hannus	2008	10	Overview
M14	Construction ICT - E-CORE workshop	By Matti Hannus	2002	4	Overview
M15	Strategic Roadmap towards knowledge-driven sustainable construction (ROADCON): Construction ICT Roadmap ROADCON project consists of 5 Work Packages WP1: ROADCON Co-ordination and management; WP2: Management Procedures for an Integrated Project; WP3: Shared and global vision; WP4: Construction ICT Framework; WP5: The ROADCON roadmap	European Construction Technology Platform (ECTP)	2003	77	Overview
M16	Centre for Smart Infrastructure and Construction Roadmap (only hardcopy; no link)	Innovation Knowledge Centre for Smart Infrastructure and Construction University of Cambridge	2011	67	Overview
M17	Centre for Smart Infrastructure and Construction Roadmap workshop brief (only hardcopy; no link)	Innovation Knowledge Centre for Smart Infrastructure and Construction University of Cambridge	2011	5	Overview
M18	Construction R&D Innovation Roadmap for a positive living environment for Society	European Construction Technology Platform (ECTP)	2010	12	Overview
M19	National Platform Research Priorities	National Platform	?	2	Overview
M20	Low Impact Buildings Innovation Platform	Technology Strategy Board	2009	4	Overview
M21	High Value Manufacturing Strategy	Technology Strategy Board	?	28	Overview

Ref	Title	Author / Body	Date	Pages	Scope
M21a	High Value Manufacturing Strategy – exec summary	Technology Strategy Board	?	2	Overview
M22	Energy Generation and Supply Strategy	Technology Strategy Board	?	44	Overview
M22a	Energy Generation and Supply Strategy – exec summary	Technology Strategy Board	?	4	Overview
M23	Advanced Materials Strategy	Technology Strategy Board	?	40	Overview
M23a	Advanced Materials Strategy – exec summary	Technology Strategy Board	?	4	Overview
M24	Resource Efficiency Strategy	Technology Strategy Board	?	48	Overview
M24a	Resource Efficiency Strategy – exec summary	Technology Strategy Board	?	4	Overview